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(54) Light emitting semiconductor device using gallium nitride group compound

Lichtemittierende Vorrichtung aus einer Verbindung der Galliumnitridgruppe

Dispositif émetteur de lumière utilisant des composés du groupe du nitrure de gallium

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention:

The present invention relates to a light-emitting semiconductor device using gallium nitride group compound which emits a light in the region from blue to ultraviolet, and also to a process for producing the same.

2. Description of the Prior Art:

It is known that GaN compound semiconductor can be made into a light-emitting semiconductor device, such as a light-emitting diode (LED), which emits a blue light.

The GaN compound semiconductor attracts attention because of its high light-emitting efficiency resulting from a direct transition and of its ability to emit a blue light which is one of the three primary colors.

The light-emitting diode of GaN compound semiconductor is composed of a sapphire substrate, an n-layer and an i-layer grown thereon. The n-layer of the GaN compound semiconductor with n-type conduction is directly grown on the surface of the sapphire substrate or grown on a buffer layer of aluminum nitride formed on the sapphire substrate. The i-layer of semi-insulating (i-type) GaN compound semiconductor is doped with p-type impurities. (See Japanese Patent Laid-open Nos. JP-A- 62119196 and JP-A-63188977.)

The voltage for driving this light-emitting diode, however, is high. Consequently, there is room for improvement.

Another disadvantage of the gallium nitride compound semiconductor is that it does not become p-type but remains i-type (semi-insulator) even though it is doped with p-type impurities.

As the results of extensive studies, the present inventors succeeded in producing a p-type gallium nitride compound semiconductor. This led to the creation of a pn junction that emits a blue light efficiently.

H. Amano et al. describe in "Japanese Journal of Applied Physics, Vol. 28, No. 12, December 1989, pp. L2112-L2114" that p-type conduction is realized with Mg-doped GaN by a low-energy electron beam irradiation treatment for providing a p-n junction LED. The p-n junction was fabricated by growing undoped n-type GaN on a saphire substrate using an AlN buffer layer, followed by growing a GaN:Mg film. Then, a small portion of the latter film was treated by the low-energy electron beam irradiation treatment, and an Al electrode was deposited on that portion. A second Al electrode was also deposited on the side of the n-type GaN for ohmic contact.

The EP-A-0 277 597 describes a gallium nitride group compound semiconductor comprising in the following order a saphire substrate, an AlN buffer layer, an n-type GaN layer, and an i-type GaN layer formed in portions on the n-layer. One type of electrode is formed on the i-layer, and another type of electrode is connected to the underlying n-layer through conductive shafts which are intermittently formed between the i-layer portions.

The JP-A-2042770 describes the production of a light-emitting element by providing an $Al_xGa_{1-x}N$-layer (including x = 0) which is doped with impurity by irradiation with an electron beam under specific conditions.

The light-emitting diode comprising the pn junction, however, presents a problem associated with insulating the electrode for a lower layer from an upper layer in case that the electrode for the lower layer is formed through the upper layer to get the electrode on the upper layer, because the p-layer and n-layer are electrically conductive.

SUMMARY OF THE INVENTION

The present invention was completed to solve this problem. It is an object of the present invention to provide a light-emitting semiconductor device using gallium nitride group compound which has a new pn junction and a new structure for leading the electrodes. This light-emitting device operates at a lower voltage.

This object is solved by a light-emitting semiconductor device according to any one of claims 1, 4 and 6 and the related methods of manufacture according to claims 8, 9 and 11.

According to an embodiment of the present invention, the pn junction is made of gallium nitride compound semiconductor ($Al_xGa_{1-x}N$, where $0 \leqq x < 1$) and the electrodes for the p-layer and n-layer are led from either p-layer or n-layer, whichever upper.

The p-layer of gallium nitride compound semiconductor is formed in the following manner. First, gallium nitride compound semiconductor is formed by a vapor phase epitaxy. During the vapor phase epitaxy, the gallium nitride compound semiconductor is doped with p-type impurities to form a semi-insulating i-layer. The i-layer is irradiated with electron rays to form the p-layer of p-type semiconductor. The p-layer is jointed with the n-layer to form the pn junction. The respective electrodes for the p-layer and n-layer are formed on the upper layer. The electrode for the lower layer is connected through a groove or hole made in the upper layer.

The upper layer has another groove formed therein which electrically insulates and separates the above mentioned groove and the electrode for the lower layer formed through this groove. The electrode for the upper layer is formed in the region separated by the groove and opposite to the other electrode.

The p-layer is doped with, for example, magnesium (Mg). Simple doping gives rise to an i-type (insulating) semiconductor, and the i-type layer changes into the p-layer upon irradiation with electron rays. This irradiation is carried out at an acceleration voltage of 1 Kv to 50 Kv

and a sample current of 0.1 μA to 1 mA.

Because of the pn junction realized for the first time by the present inventors, it is possible to lower the operating voltage and to improve the light-emitting efficiency and the light intensity.

In addition, with the groove formed in the upper layer, it is possible to electrically insulate and separate the upper layer from the electrode for the lower layer.

The above-mentioned structure makes it possible to produce a light-emitting device having the pn junction and the bump connection (with face down) formed for both electrodes on the upper layer.

According to another embodiment of the present invention, a p-layer of gallium nitride compound semiconductor ($Al_xGa_{1-x}N$, where $0 \leqq x < 1$) is formed on an n-layer, and part of the i-layer is converted into p-type, so that a partial pn junction is formed, and the electrodes for both layers are led from the upper i-layer. This structure is produced in the following manner.

First, an n-layer is formed from an n-type gallium nitride compound semiconductor. An i-layer of gallium nitride compound semiconductor doped with p-type impurities is formed on the n-layer. Upon doping with the p-type impurities, the gallium nitride compound semiconductor becomes an insulator although it does not change into p-type.

The electrode for the n-layer is formed on the surface of the i-layer through a groove formed in the i-layer so that the groove reaches the n-layer. A p-type part is formed on the specific region of the i-layer so that the electrode for the n-layer is insulated and separated by the i-layer. The p-type part is formed by irradiating the specific region of the i-layer with electron rays. In other words, the i-type (insulating) gallium nitride compound semiconductor decreases in resistance upon irradiation with electron rays, changing into a p-type semiconductor. The thus converted p-layer and the lower n-layer form the pn junction. An electrode for the p-type part is formed on this p-type part.

Thus the electrode for the lower n-layer is insulated and separated from the p-type part by the i-layer.

The i-layer is doped with, for example, magnesium (Mg). The irradiation is carried out at an acceleration voltage of 1 kV to 50 kV and a sample current of 0.1 μA to 1 mA.

Because of the pn junction realized for the first time by the present inventors as mentioned above, it is possible to lower the operating voltage.

As mentioned above, the electrode for the lower n-layer is insulated and isolated from the p-layer by the i-layer. This structure makes it possible to produce a light-emitting device having the bump connection (with face down) formed for both electrodes on the upper p-layer and i-layer.

In still another embodiment of the present invention, besides the provision of an n-layer of n-type gallium nitride group compound semiconductor ($Al_xGa_{1-x}N$, where $0 \leq x < 1$) and a p-layer of gallium nitride group compound semiconductor ($Al_xGa_{1-x}N$, where $0 \leq x < 1$) which exhibits the p-type conduction upon doping with p-type impurities and irradiation with electron rays, the light-emitting semiconductor device comprises an n-layer of n-type gallium nitride group compound semiconductor ($Al_xGa_{1-x}N$, where $0 \leq x < 1$) joining said p-layer. A first electrode for said p-layer is formed on an upper surface of said n-layer so as to join to said p-layer, passing through a first groove formed in said n-layer which extends from said upper surface of said n-layer to said p-layer, and a second electrode for said n-layer is formed in a region opposite to said first electrode, said region being on said upper surface of said n-layer and being separated from said first electrode by a second groove formed in said n-layer so as to extend from said upper surface of said n-layer to said p-layer.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic representation showing a structure of a light-emitting diode according to a first embodiment of the present invention.

Figs. 2 to 7 are sectional views showing the process of producing the light-emitting diode according to a first embodiment of the present invention.

Figs. 8A and 8B are graphs showing measured V-I characteristics of the pn type LED described in Example 1 and a MIS type LED, respectively.

Fig. 9 is a sectional view showing a structure of a light-emitting diode according to a second embodiment of the present invention.

Figs. 10 to 16 are sectional views showing the process of producing the light-emitting diode according to a second embodiment of the present invention.

Figs. 17A and 17B are graphs showing measured V-I characteristics of the pn type LED described in Example 2 and a MIS type LED, respectively.

Fig. 18 is a sectional view showing a structure of a light-emitting diode according to a third embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention will be described in more detail with reference to the following examples.

Example 1

A light-emitting diode 10 as shown in Fig. 1 is composed of a sapphire substrate 1 and several layers formed thereon which include a 50nm (500 Å) thick buffer layer 2 of AlN, a 2.2 μm thick n^+-layer 3 of GaN with a high carrier concentration, a 1.5 μm thick n-layer 4 of GaN with a low carrier concentration and a 0.2 μm thick p-layer 5 of GaN. An electrode 7 of aluminum is in contact with the p-layer 5, and an electrode 8 of aluminum is in contact with the n^+-layer 3. The electrodes 7 and 8

are separated from each other by a groove 9.

The light-emitting diode 10 of the above-mentioned structure was produced by the metalorganic vapor phase epitaxy (MOVPE) in the following manner. This process employed NH_3, H_2 (carrier gas), trimethyl gallium $Ga(CH_3)_3$ (TMG), trimethyl aluminum $Al(CH_3)_3$ (TMA), silane SiH_4, and cyclopentadienyl magnesium $Mg(C_5H_5)_2$ (CP_2Mg).

The process started with cleaning the single crystal sapphire substrate by washing with an organic solvent and by heat treatment. The cleaned sapphire substrate 1 whose principal surface was a-surface {1120} was placed on the susceptor mounted in a reaction chamber of an MOVPE apparatus. The sapphire substrate 1 underwent vapor phase etching at 1100°C with hydrogen flowing through the reaction chamber at a rate of 2 liters/min under normal pressure. The reaction chamber in which the temperature was lowered at 400°C was supplied with H_2 at a flow rate of 20 liters/min, NH_3 at a flow rate of 10 liters/min, and TMA at a flow rate of 1.8×10^{-5} mol/min, so as to form the 50nm (500 Å) thick buffer layer 2 of AlN.

With the sapphire substrate 1 kept at 1150°C, the reaction chamber was supplied with H_2 at a flow rate of 20 liters/min, NH_3 at a flow rate of 10 liters/min, TMG at a flow rate of 1.7×10^{-4} mol/min, and silane SiH_4 (diluted to 0.86 ppm with H_2) at a flow rate of 200 ml/min for 30 minutes, so as to form the 2.2 μm thick n^+-layer 3 of GaN with a high carrier concentration ($1.5 \times 10^{18}/cm^3$).

With the sapphire substrate 1 kept at 1150°C, the reaction chamber was supplied with H_2 at a flow rate of 20 liters/min, NH_3 at a flow rate of 10 liters/min, and TMG at a flow rate of 1.7×10^{-4} mol/min for 20 minutes, so as to form the 1.5 μm thick n-layer 4 of GaN with a low carrier concentration ($1 \times 10^{15}/cm^3$).

With the sapphire substrate 1 kept at 900°C, the reaction chamber was supplied with H_2 at a flow rate of 20 liters/min, NH_3 at a flow rate of 10 liters/min, TMG at a flow rate of 1.7×10^{-4} mol/min, and CP_2Mg at a flow rate of 3×10^{-6} mol/min for 3 minutes, so as to form the 0.2 μm thick i-layer 5 of GaN. The i-layer 5 as such is an insulator.

The i-layer 5 was uniformly irradiated with electron rays using a reflection electron diffraction apparatus. The conditions for irradiation are as follows: Acceleration voltage: 10 kV, sample currents 1 μA, beam moving rate: 0.2 mm/sec, beam diameter: 60 μmϕ, and vacuum: 2.79 mPa (2.1×10^{-5} Torr). This irradiation changed the i-layer 5 which was an insulator having a resistivity greater than $10^8 \Omega cm$ into a conducting semiconductor having a resistivity of 40 Ωcm. In this way, there was obtained the p-layer 5 which exhibits the p-type electric conduction.

The wafer of multi-layered structure as shown in Fig. 2 was got by the above-mentioned steps. This wafer had many same elements which would be separated from one another later to make many chips. Figs. 3 to 7 are sectional views of a single device formed on the wafer.

A 0.2 μm (2000 Å) thick SiO_2 layer 11 was formed on the p-layer 5 by sputtering as shown in Fig. 3. The SiO_2 layer 11 was coated with a photoresist 12. The photoresist layer 12 was removed at positions A and B by photolithography. The position A is where a groove 15 is to be formed which reaches the n^+-layer 3 of high carrier concentration. (In the groove 15, an electrode is formed later) The position B is where the other groove 9 is to be formed which separates said electrode forming part from the electrode for the p-layer 5.

The exposed parts of the SiO_2 layer 11 which are not covered by the photoresist 12 were removed by etching with hydrofluoric acid, as shown in Fig. 4.

The exposed parts of the p-layer 5 and n-layer 4 of low carrier (which are not covered by the photoresist 12 and SiO_2 layer 11) underwent dry etching with CCl_2F_2 with Ar at a flow rate of 10 ml/min at 5.32 Pa (0.04 Torr) and at a high-frequency power, 0.44 W/cm^2 and thereafter successively underwent dry etching as shown in Fig. 5. This dry etching was carried out till the upper surface of the n^+-layer 3 was partly removed. The groove 15 for the electrode leading to the n^+-layer 3 and the other groove 9 for insulation and separation were formed by this step.

The SiO_2 layer 11 remaining on the p-layer 5 was removed by etching with hydrofluoric acid, as shown in Fig. 6.

The upper surface of the sample was entirely covered with an Al layer 13 by vapor deposition, as shown in Fig. 7. The Al layer 13 was electrically connected to the n^+-layer 3 through the groove 15.

The Al layer 13 was coated with a photoresist 14, which was subsequently patterned by photolithography so that the electrode leading to the n^+-layer 3 and p-layer 5 remained.

The exposed part of the Al layer 13 not covered with the photoresist 14 underwent etching with nitric acid, with the photoresist 14 as a mask, as shown in Fig. 7. This etching completely removed the Al layer 13 formed by deposition on the inside of the groove 9. The photoresist 14 was removed with acetone. There remained the electrode 8 for the n^+-layer 3 and the electrode for the p-layer 5.

After the above-mentioned steps, the wafer was cut into individual chips. Thus there was obtained a gallium nitride light-emitting diode having the pn junction structure, as shown in Fig. 1.

The voltage-current (V-I) characteristics of the light-emitting diode (pn junction type LED) 10 produced as mentioned above was measured. The result is shown in Fig. 8A. On the contrary the V-I characteristics of a conventional MIS (metal insulator semiconductor) type LED having an n-layer and a semi-insulating i-layer was measured. The result is shown in Fig. 8B. From the Figs. 8A and 8B it is known that the drive voltage at a drive current of 10 mA is about 8 volts in the pn junction type LED and the drive voltage is about 13 volts in the MIS

type LED. Accordingly, the drive voltage is lower in the pn junction type LED than in the MIS type LED. From many measurements for many samples of the pn and MIS type LED's it was observed that the drive voltages of the pn type LED's little fluctuate but the drive voltages concerning the MIS type LED's fluctuate from 10 V to 15 V.

The magnesium doping gas used in the above-mentioned embodiment may be replaced by methylcyclopentadienyl magnesium Mg $(C_5H_5)CH_3$.

In the above-mentioned embodiment, the n-layer is of double-layer structure composed of the n^+-layer 3 of high carrier concentration and the n-layer 4 of low carrier concentration. However, these two layers may be replaced by a single n-layer.

In the case of the double-layer structure, the n-layer 4 of low carrier concentration should preferably have a carrier concentration of 1 x 10^{14} to 1 x $10^{17}/cm^3$ and a thickness of 0.5 to 2 μm. With a carrier concentration higher than 1 x $10^{17}/cm^3$, the light-emitting diode decreases in light intensity. With a carrier concentration lower than 1 x $10^{14}/cm^3$, the light-emitting diode radiates heat because of the increased serial resistance. With a thickness greater than 2 μm, the light-emitting diode radiates heat because of the increased serial resistance. With a thickness smaller than 0.5 μm, the light-emitting diode decreases in light intensity.

In addition, the n^+-layer 3 should preferably have a carrier concentration of 1 x 10^{17} to 1 x $10^{19}/cm^3$ and a thickness of 2 to 10 μm. A carrier concentration higher than 1 x $10^{19}/cm^3$ is not desirable because crystal property becomes poor. With a carrier concentration lower than 1 x $10^{17}/cm^3$, the light-emitting diode radiates heat because of the increased serial resistance. A layer thickness greater than 10 μm would cause the substrate to warp. With a layer thickness smaller than 2 μm, the light-emitting diode radiates heat because of the increased serial resistance.

Example 2

A light-emitting diode 10 as shown in Fig. 9 is composed of a sapphire substrate 1 and several layers formed thereon which include a 50nm (500 Å) thick buffer layer 2 of AlN, a 2.2 μm thick n^+-layer 3 of GaN with a high carrier concentration, a 1.5 μm thick n-layer 4 of GaN with a low carrier concentration, a 0.2 μm thick i-layer 50 of GaN, and a p-layer 5 which exhibits the p-type electric conduction. The p-layer 5 is formed in a part of the i-layer 50.

There is a groove 15 which passes through the i-layer 50 and the n-layer 4 of low carrier concentration, reaching the n^+-layer 3 of high carrier concentration. There is an electrode 52 of aluminum which is formed on the i-layer 50 and is connected to the n^+-layer 3 of high carrier concentration through the groove 15. On the p-layer 5 is formed an electrode 51 of aluminum for the p-layer 5. The electrode 52 for the n^+-layer 3 of high carrier concentration is insulated and separated from the p-layer 5 by the i-layer 50.

The light-emitting diode 10 of the above-mentioned structure was produced by MOVPE in the following manner. This process employed NH_3, H_2 (carrier gas), TMG, TMA, silane SiH_4, and CP_2Mg.

The following steps gave rise to a wafer of multi-layered structure as shown in Fig. 9. This wafer was processed into a multiplicity of elements which were separated from one another later. Figs. 10 to 16 are sectional views of a single device formed on the wafer.

The process started with cleaning a single-crystal sapphire substrate by washing with an organic solvent and by heat treatment. The cleaned sapphire substrate 1 (whose a-plane is the principal surface) was placed on the susceptor mounted in the reaction chamber of the MOVPE apparatus. The sapphire substrate 1 underwent vapor phase etching at 1100°C with hydrogen flowing through the reaction chamber at a rate of 2 liters/min under normal pressure. The reaction chamber in which the temperature was lowered at 400°C was supplied with H_2 at a flow rate of 20 liters/min, NH_3 at a flow rate of 10 liters/min, and TMA at a flow rate of 1.8 x 10^{-5} mol/min, so as to form a 50nm (500 Å) thick buffer layer 2 of AlN.

With the sapphire substrate 1 kept at 1150°C, the reaction chamber was supplied with H_2 at a flow rate of 20 liters/min, NH_3 at a flow rate of 10 liters/min, TMG at a flow rate of 1.7 x 10^{-4} mol/min, and silane SiH_4 (diluted to 0.86 ppm with H_2) at a flow rate of 200 ml/min for 30 minutes, so as to form a 2.2 μm thick n^+ layer 3 of GaN with a high carrier concentration (1.5 x $10^{18}/cm^3$).

With the sapphire substrate 1 kept at 1150°C, the reaction chamber was supplied with H_2 at a flow rate of 20 liters/min, NH_3 at a flow rate of 10 liters/min, and TMG at a flow rate of 1.7 x 10^{-4} mol/min for 20 minutes, so as to form a 1.5 μm thick n-layer 4 of GaN with a low carrier concentration (1 x $10^{15}/cm^3$).

With the sapphire substrate 1 kept at 900°C, the reaction chamber was supplied with H_2 at a flow rate of 20 liters/min, NH_3 at a flow rate of 10 liters/min, TMG at a flow rate of 1.7 x 10^{-4} mol/min, and CP_2Mg at a flow rate of 3 x 10^{-6} mol/min for 3 minutes, so as to form a 0.2 μm thick i-layer 50 of GaN. The i-layer 50 as such was an insulator.

On the i-layer 50 was formed an SiO_2 layer 11 0,2 μm (2000 Å thick) by sputtering, as shown in Fig. 11. The SiO_2 layer 11 was coated with a photoresist 12. The photoresist at position A was removed by photolithography, where a groove 15 was to be formed later which passed through the i-layer 50 and the n-layer 4. The exposed part of the SiO_2 layer 11 (which was not covered by the photoresist 12) was removed by etching with hydrofluoric acid, as shown in Fig. 12.

The exposed parts of the i-layer 50 and n-layer 4 (which are not covered by the photoresist 12 and the SiO_2 layer 11) underwent dry etching with CCl_2F_2 at a flow rate of 10 ml/min at 5.32 Pa (0.04 Torr) and 0.44

W/cm^2 (high-frequency power) and thereafter successively dry etching with Ar. This dry etching was carried out till the surface of the n^+-layer 3 was etched. A groove 15 for the electrode leading to the n^+-layer 3 was formed by this step, as shown in Fig. 13.

The SiO_2 layer 11 remaining on the i-layer 50 was removed by etching with hydrofluoric acid, as shown in Fig. 14.

The i-layer 50 was locally irradiated with electron rays using a reflection electron diffraction apparatus to form a p-type part 5 which was p-type semiconductor, as shown in Fig. 15. The conditions for irradiation were as follows: Acceleration voltage: 10 kV, sample current: 1 μA, beam moving rate: 0.2 mm/sec, beam diameter: 60 μmφ, and vacuum: 2.79 mPa (2.1 x 10^{-5} Torr). This irradiation changed the i-layer 50 (which was an insulator having a resistivity greater than 10^8 Ωcm) into a p-type semiconductor having a resistivity of 35 Ωcm. The part other than the p-type part 5 (i.e., the part which was not irradiated with electron rays) remained the i-layer 50 which was an insulator. Therefore, the p-type part 5 formed the pn junction with the n-layer 4 in the vertical direction; but it was electrically isolated and insulated from its surrounding by the i-layer 50 in the horizontal direction.

An Al layer 20 was formed to cover the p-type part 5, the i-layer 50, and the inside of the groove 15, as shown in Fig. 16. The Al layer 20 was coated with a photoresist layer 21, which was to be subsequently patterned by photolithography so that electrodes for the n^+-layer 3 and the p-type part 5 remained unetched.

The exposed part of the Al layer 20 underwent etching with nitric acid, with the photoresist 21 as a mask. The photoresist 21 was removed with acetone. In this way there were formed the first electrode 52 for the n^+-layer 3 and the second electrode 51 for the p-type part 5, as shown in Fig. 9. After the above-mentioned steps, the wafer was cut into individual elements.

The V-I characteristics of the light-emitting diode (pn junction type LED) 10 produced as mentioned above was measured as well as in the example 1. The result is shown in Fig. 17A. The V-I characteristics of a conventional MIS type LED having an n-layer and a semi-insulating i-layer is shown in Fig. 17B. From the Figs. 17A and 17B it is known that the drive voltage at a drive current of 10 mA is about 8 volts in the pn junction type LED and the drive voltage is about 13 volts in the MIS type LED. Accordingly, the drive voltage is lower in the pn junction type LED than in the MIS type LED. From many measurements for many samples of the pn and MIS type LED's it was observed that the drive voltages of the pn type LED's little fluctuate but the drive voltages concerning the MIS type LED's fluctuate from 10 V to 15 V.

The magnesium doping gas used in the above-mentioned embodiment may be replaced by methylcyclopentadienyl magnesium Mg $(C_5H_5)CH_3$.

Example 3

A light-emitting diode 10 as shown in Fig. 18 is composed of a sapphire substrate 1 and several layers formed thereon which include a 50nm (500 Å) thick buffer layer 2 of AlN, a 0.2 μm thick p-layer 5 of GaN, a 1.5 μm thick n-layer 4 of GaN with a low carrier concentration and a 2.2 μm thick n^+-layer 3 of GaN with a high carrier concentration. An electrode 8 of aluminum is in contact with the n^+-layer 3, and an electrode 7 of aluminum is in contact with the p-layer 5. The electrodes 7 and 8 are separated from each other by a groove 9.

The light-emitting diode 10 of the above-mentioned structure was produced by the metalorganic vapor phase epitaxy (MOVPE) in the same manner as the example 1.

In the example 3, the order of forming the p-layer 5, the n-layer 4 and the n^+-layer 3 is only different from the example 1.

In the above-mentioned embodiment, the n-layer is of double-layer structure composed of an n^+-layer 3 of high carrier concentration and an n-layer 4 of low carrier concentration. However, these two layers may be replaced by a single n-layer.

In the case of double-layer structure, the n-layer should preferably have a carrier concentration of 1 x 10^{14} to 1 x $10^{17}/cm^3$ and a thickness of 0.5 to 2 μm. With a carrier concentration higher than 1 x $10^{17}/cm^3$, the light-emitting diode decreases in light intensity. With a carrier concentration lower than 1 x $10^{14}/cm^3$, the light-emitting diode radiates heat because of the increased serial resistance. With a thickness greater than 2 μm, the light-emitting diode radiates heat because of the increased serial resistance. With a thickness smaller than 0.5 μm, the light-emitting diode decreases in light intensity.

In addition, the n^+-layer 3 should preferably have a carrier concentration of 1 x 10^{17} to 1 x $10^{19}/cm^3$ and a thickness of 2 to 10 μm. A carrier concentration higher than 1 x $10^{19}/cm^3$ is not desirable because crystal property becomes poor. With a carrier concentration lower than 1 x $10^{17}/cm^3$, the light-emitting diode radiates heat because of the increased serial resistance. A layer thickness greater than 10 μm would cause the substrate to warp. With a layer thickness smaller than 2 μm, the light-emitting diode radiates heat because of the increased serial resistance.

Claims

1. A light-emitting semiconductor device (10) using gallium nitride group compound comprising:

   an n-layer of n-type gallium nitride group compound semiconductor ($Al_xGa_{1-x}N$, where $0 \leq x < 1$);
   a p-layer (5) of gallium nitride group compound

semiconductor ($Al_xGa_{1-x}N$, where $0 \le x < 1$) which exhibits the p-type conduction upon doping with p-type impurities and irradiation with electron rays, said p-layer (5) joining to said n-layer;

a first electrode (8) for said n-layer which is formed on an upper surface of said p-layer (5) so as to join to said n-layer, passing through a first groove (15) formed in said p-layer (5) which extends from said upper surface of said p-layer to said n-layer; and

a second electrode (7) for said p-layer which is formed in a region opposite to said first electrode (8), said region being on said upper surface of said p-layer (5) and being separated from said first electrode (8) by a second groove (9) formed in said p-layer (5) so as to extend from said upper surface of said p-layer to said n-layer.

2. A light-emitting device according to Claim 1, wherein said n-layer is of double-layer structure composed of an n-layer (4) of low carrier concentration in which the electron density is low and an n^+-layer (3) of high carrier concentration in which the electron density is high, with the former layer joining to said p-layer (5) and said first electrode (8) joins to said n^+-layer (3) of high carrier concentration.

3. A light-emitting device according to Claim 2, which further comprises a sapphire substrate (1) and a buffer layer (2) of aluminum nitride (AlN) formed thereon, with said n^+-layer (3) of high carrier concentration being formed on said buffer layer (2).

4. A light-emitting semiconductor device using gallium nitride group compound comprising:

a p-layer (5) of gallium nitride group compound semiconductor ($Al_xGa_{1-x}N$, where $0 \le x < 1$) which exhibits the p-type conduction upon doping with p-type impurities and irradiation with electron rays;

an n-layer of n-type gallium nitride group compound semiconductor ($Al_xGa_{1-x}N$, where $0 \le x < 1$), said n-layer joining to said p-layer (5);

a first electrode (7) for said p-layer (5) which is formed on an upper surface of said n-layer so as to join to said p-layer (5), passing through a first groove formed in said n-layer which extends from said upper surface of said n-layer to said p-layer (5); and

a second electrode (8) for said n-layer which is formed in a region opposite to said first electrode, said region being on said upper surface of said n-layer and being separated from said first electrode (7) by a second groove (9) formed in said n-layer so as to extend from said upper surface of said n-layer to said p-layer (5).

5. A light-emitting device according to Claim 4, wherein said n-layer is of double-layer structure composed of an n-layer (4) of low carrier concentration in which the electron density is low and an n^+-layer (3) of high carrier concentration in which the electron density is high, with the former layer joining to said p-layer (5), and said second electrode (8) is formed on said n^+-layer (3) of high carrier concentration.

6. A light-emitting semiconductor device using gallium nitride group compound comprising:

an n-layer of n-type gallium nitride group compound semiconductor ($Al_xGa_{1-x}N$, where $0 \le x < 1$);

an i-layer (50) of semi-insulator of gallium nitride group compound semiconductor ($Al_xGa_{1-x}N$, where $0 \le x < 1$) doped with p-type impurities, said i-layer (50) joining to said n-layer;

a first electrode (52) for said n-layer which is formed on an upper surface of said i-layer (50) so as to join to said n-layer, passing through a first groove (15) formed in said i-layer (50) which extends from said upper surface of said i-layer to said n-layer;

wherein said n-layer is of double-layer structure composed of an n-layer (4) of low carrier concentration in which the electron density is low and an n^+-layer (3) of high carrier concentration in which the electron density is high, with the former layer joining to said i-layer (50), and said first electrode (52) joins to said n^+-layer (3) of high carrier concentration;

a p-type part (5) in a specific region in said i-layer (50) which is converted into p-type conduction by irradiation with electron rays, said p-type part being formed such that said first electrode (52) is insulated and separated from said p-type part (5) by said i-layer (50); and

a second electrode (51) for said p-type part (5) which is formed on an upper surface of said p-type part (5).

7. A light-emitting device according to Claim 6, which further comprises a sapphire substrate (1) and a buffer layer (2) of aluminum nitride (AlN) formed thereon, with said n^+-layer (3) of high carrier concentration being formed on said buffer layer (2).

8. A process for producing a light-emitting semiconductor device (10) using gallium nitride group compound comprising the steps of:

forming an i-layer (5) of semi-insulator of gallium nitride group compound semiconductor ($Al_xGa_{1-x}N$, where $0 \leq x < 1$) doped with p-type impurities on an n-layer of n-type gallium nitride group compound semiconductor ($Al_xGa_{1-x}N$, where $0 \leq x < 1$);

converting said i-layer (5) into a p-layer (5) which exhibits p-type conduction by irradiating said i-layer with electron rays;

forming in said p-layer (5) a first groove (15) extending from an upper surface of said p-layer to said n-layer in which a first electrode (8) for said n-layer is to be formed and also forming in said p-layer a second groove (9) for separating said first electrode forming groove (15) from a second electrode (7) to be formed on said p-layer (5) in a region thereof opposite to said first electrode (8)

forming on said p-layer (5) surrounding said first groove (15) said first electrode (8) for said n-layer which passes through said first groove to join to said n-layer; and

forming on said upper surface of said p-layer (5) separated by said second groove (9) said second electrode (7) for said p-layer (5).

9. A process for producing a light-emitting semiconductor device (10) using gallium nitride group compound comprising:

forming an i-layer (5) of semi-insulator of gallium nitride compound semiconductor ($Al_xGa_{1-x}N$, where $0 \leq x < 1$) doped with p-type impurities;

converting said i-layer (5) into a p-layer (5) which exhibits p-type conduction by irradiating said i-layer with electron rays;

forming on said p-layer (5) an n-layer of gallium nitride group compound semiconductor ($Al_xGa_{1-x}N$, where $0 \leq x < 1$);

forming in said n-layer a first groove (15) extending from an upper surface of said n-layer to said p-layer in which a first electrode (7) for said p-layer is to be formed and also forming in said n-layer a second groove (9) for separating said first electrode forming groove (15) from a second electrode (8) to be formed on said n-layer in a region thereof opposite to said first electrode (7);

forming on said n-layer surrounding said first groove (15) said first electrode (7) for said p-layer (5) which passes through said first groove to join to said p-layer; and

forming on said upper surface of said n-layer separated by said second groove (9) said second electrode (8) for said n-layer.

10. A process according to Claim 8 or 9, wherein irradiation with electron rays is carried out at an acceleration voltage of 1 kV to 50 kV and a sample current of 0.1 μA to 1 mA.

11. A process for producing a light-emitting semiconductor device using gallium nitride group compound comprising:

forming an n-layer of n-type gallium nitride group compound semiconductor ($Al_xGa_{1-x}N$, where $0 \leq x < 1$) with a double-layer structure by first forming an n^+-layer (3) of high carrier concentration in which the electron density is high, and then forming an n-layer (4) of low carrier concentration in which the electron density is low;

forming an i-layer (50) of semi-insulator of gallium nitride group compound semiconductor ($Al_xGa_{1-x}N$, where $0 \leq x < 1$) doped with p-type impurities on said n-layer (4);

forming in said i-layer (50) a groove (15) extending from an upper surface of said i-layer to said n^+-layer (3) in which a first electrode (52) for said n-layer is to be formed;

forming a p-type part (5) in a specific region in said i-layer (50) which is converted into p-type conduction by irradiating with electron rays, said p-type part (5) being formed such that said groove (15) is separated from said p-type part (5) by said i-layer (50);

forming on said i-layer (50) surrounding said groove (15) a first electrode (52) for said n-layer which passes through said groove (15) to join to said n^+-layer (3); and

forming on an upper surface of said p-type part (5) a second electrode (51) for said p-type part.

Patentansprüche

1. Lichtemittierende Halbleiter-Vorrichtung (10), die eine Verbindung einer Galliumnitridgruppe verwendet, umfassend:

eine n-Schicht eines n-leitenden Halbleiters einer Verbindung einer Galliumnitridgruppe ($Al_xGa_{1-x}N$, worin $0 \leq x < 1$);

eine p-Schicht (5) vom Halbleiter einer Verbindung einer Galliumnitridgruppe ($Al_xGa_{1-x}N$, worin $0 \leq x < 1$), die die p-Leitung, nach dem Dotieren mit p-leitenden Verunreinigungen und Bestrahlen mit Elektronenstrahlen, zeigt, wobei diese p-Schicht (5) mit dieser n-Schicht in Verbindung steht;

eine erste Elektrode (8) für diese n-Schicht, die auf der oberen Oberfläche von dieser p-Schicht (5) gebildet ist, um so eine Verbindung zu dieser n-Schicht herzustellen, die durch eine erste

Rille (15) durchführt, die in dieser p-Schicht (5) gebildet ist, die sich von dieser oberen Oberfläche von dieser p-Schicht zu dieser n-Schicht erstreckt; und

eine zweite Elektrode (7) für diese p-Schicht, die in einem Bereich gebildet ist, der gegenüber von dieser ersten Elektrode (8) ist, wobei dieser Bereich auf dieser oberen Oberfläche von dieser p-Schicht (5) ist und von dieser ersten Elektrode (8) mittels einer zweiten Rille (9) getrennt ist, die in dieser p-Schicht (5) gebildet ist, um sich so von dieser oberen Oberfläche der p-Schicht zu dieser n-Schicht zu erstrecken.

2. Lichtemittierende Vorrichtung nach Anspruch 1, worin die n-Schicht von einer Doppelschicht-Struktur ist, die sich aus einer n-Schicht (4) von niedriger Ladungskonzentration, in der die Elektronendichte niedrig ist und einer n^+-Schicht (3) von hoher Ladungskonzentration, in der die Elektronendichte hoch ist, mit der erstgenannten Schicht, die zu dieser p-Schicht (5) in Verbindung steht und dieser ersten Elektrode (8) zusammensetzt, die mit dieser n^+-Schicht (3) von hoher Ladungskonzentration in Verbindung steht.

3. Lichtemittierende Vorrichtung nach Anspruch 2, die des weiteren ein Saphirsubstrat (1) und eine Pufferschicht (2) aus Aluminiumnitrid (AlN), die darauf gebildet ist, mit dieser n^+-Schicht (3) von hoher Ladungskonzentration, die auf dieser Pufferschicht gebildet ist, enthält.

4. Lichtemittierende Halbleiter-Vorrichtung, die eine Verbindung einer Galliumnitridgruppe verwendet, umfassend:

eine p-Schicht (5) eines Halbleiters einer Verbindung einer Galliumnitridgruppe ($Al_xGa_{1-x}N$, worin $0 \leq x < 1$), die die p-Leitung, nach dem Dotieren mit p-leitenden Verunreinigungen und Bestrahlen mit Elektronenstrahlen, zeigt;

eine n-Schicht eines n-leitenden Halbleiters einer Verbindung einer Galliumnitridgruppe ($Al_xGa_{1-x}N$, worin $0 \leq x < 1$), wobei diese n-Schicht zu dieser p-Schicht (5) in Verbindung steht;

eine erste Elektrode (7), die für diese p-Schicht (5) auf der oberen Oberfläche von dieser n-Schicht gebildet ist, um so eine Verbindung zu dieser p-Schicht (5) herzustellen, die durch eine erste Rille durchführt, die in dieser n-Schicht gebildet ist, die sich von dieser oberen Oberfläche von dieser n-Schicht zu dieser p-Schicht (5) erstreckt; und

eine zweite Elektrode (8) für diese n-Schicht, die in einem Bereich gebildet ist, der gegenüber von dieser ersten Elektrode ist, wobei dieser Bereich auf dieser oberen Oberfläche von dieser n-Schicht ist und von dieser ersten Elektrode (7) mittels einer zweiten Rille (9) getrennt ist, die in dieser n-Schicht gebildet ist, um sich so von dieser oberen Oberfläche der n-Schicht zu dieser p-Schicht (5) zu erstrecken.

5. Lichtemittierende Vorrichtung nach Anspruch 4, worin die n-Schicht von einer Doppelschicht-Struktur ist, die sich aus einer n-Schicht (4) von niedriger Ladungskonzentration, in der die Elektronendichte niedrig ist und einer n^+-Schicht (3) von hoher Ladungskonzentration, in der die Elektronendichte hoch ist, mit der erstgenannten Schicht, die zu dieser p-Schicht (5) in Verbindung steht und dieser ersten Elektrode (8) zusammensetzt, die auf dieser n^+-Schicht (3) von hoher Ladungskonzentration gebildet ist.

6. Lichtemittierende Halbleiter-Vorrichtung, die eine Verbindung einer Galliumnitridgruppe verwendet, umfassend:

eine n-Schicht eines n-leitenden Halbleiters einer Verbindung einer Galliumnitridgruppe ($Al_xGa_{1-x}N$, worin $0 \leq x < 1$);

eine i-Schicht (50) eines Halbleiters einer Verbindung einer Galliumnitridgruppe ($Al_xGa_{1-x}N$, worin $0 \leq x < 1$), die mit p-leitenden Verunreinigungen dotiert ist, wobei diese i-Schicht (50) mit dieser n-Schicht in Verbindung steht;

eine erste Elektrode (52) für diese n-Schicht, die auf der oberen Oberfläche von dieser i-Schicht (50) gebildet ist, um so eine Verbindung zu dieser n-Schicht herzustellen, die durch eine erste Rille (15) durchführt, die in dieser i-Schicht (50) gebildet ist, die sich von dieser oberen Oberfläche von dieser i-Schicht zu dieser n-Schicht erstreckt;

worin die n-Schicht von einer Doppelschicht-Struktur ist, die sich aus einer n-Schicht (4) von niedriger Ladungskonzentration, in der die Elektronendichte niedrig ist und einer n^+-Schicht (3) von hoher Ladungskonzentration, in der die Elektronendichte hoch ist, mit der erstgenannten Schicht, die zu dieser i-Schicht (50) in Verbindung steht und dieser ersten Elektrode (52) zusammensetzt, die zu dieser n^+-Schicht (3) von hoher Ladungskonzentration in Verbindung steht;

einen p-leitenden Bereich (5) in einem speziellen Bereich in dieser i-Schicht (50), die in eine p-Leitung, mittels Bestrahlung mit Elektronenstrahlen, umgewandelt wird, wobei dieser p-leitenden Bereich so gebildet ist, daß diese erste Elektrode (52) von diesem p-leitenden Bereich (5) mittels der i-Schicht (50) isoliert und getrennt ist; und

eine zweite Elektrode (51) für diesen p-leitenden Bereich (5), die auf der oberen Oberfläche von diesem p-leitenden Bereich gebildet ist.

7. Lichtemittierende Vorrichtung nach Anspruch 6, die des weiteren ein Saphirsubstrat (1) und eine Pufferschicht (2) aus Aluminiumnitrid (AlN), das darauf gebildet ist, mit dieser n^+-Schicht (3) von hoher Ladungskonzentration, die auf dieser Pufferschicht (2) gebildet ist, enthält.

8. Verfahren zur Herstellung einer lichtemittierenden Vorrichtung (10), die eine Verbindung einer Galliumnitridgruppe verwendet, umfassend die Schritte:

   Bildung einer i-Schicht (5) des Halbleiters einer Verbindung einer Galliumnitridgruppe ($Al_x Ga_{1-x}N$, worin $0 \leq x < 1$), die mit p-leitenden Verunreinigungen dotiert wird, auf einer n-Schicht eines n-leitenden Halbleiters einer Verbindung einer Galliumnitridgruppe ($Al_xGa_{1-x}N$, worin $0 \leq x < 1$);
   Umwandlung dieser i-Schicht (5) in eine p-Schicht (5), die eine p-Leitung zeigt, mittels Bestrahlung von dieser i-Schicht mit Elektronenstrahlen;
   Bildung einer ersten Rille (15) in dieser p-Schicht (5), die sich von einer oberen Oberfläche von dieser p-Schicht zu dieser n-Schicht erstreckt, in der eine erste Elektrode (8) für diese n-Schicht gebildet wird und es wird auch in dieser p-Schicht eine zweite Rille (9), zur Trennung von dieser ersten Elektrode, gebildet, die die Rille (15) bildet, von einer zweiten Elektrode (7), die auf dieser p-Schicht (5) in einem Bereich darauf gebildet wird, der gegenüber von dieser ersten Elektrode (8) liegt;
   Bildung von dieser ersten Elektrode (8) auf dieser p-Schicht (5), die diese erste Rille (15) umgibt, für diese n-Schicht, die durch die erste Rille durchführt, um zu dieser n-Schicht in Verbindung zu kommen; und
   Bildung auf dieser oberen Oberfläche auf dieser p-Schicht (5), getrennt von dieser zweiten Rille (9), die zweite Elektrode (7) für diese p-Schicht (5).

9. Verfahren zur Herstellung einer lichtemittierenden Halbleiter-Vorrichtung (10), die eine Verbindung einer Galliumnitridgruppe verwendet, umfassend:

   Bildung einer i-Schicht (5) eines Halbleiters einer Verbindung einer Galliumnitridgruppe ($Al_xGa_{1-x}N$, worin $0 \leq x < 1$), die mit p-leitenden Verunreinigungen dotiert wird;
   Umwandlung dieser i-Schicht (5) in eine p-Schicht (5), die eine p-Leitung zeigt, mittels Bestrahlung von dieser i-Schicht mit Elektronenstrahlen;
   Bildung einer n-Schicht eines Halbleiters einer Verbindung einer Galliumnitridgruppe ($Al_x Ga_{1-x}N$, worin $0 \leq x < 1$) auf dieser p-Schicht (5);
   Bildung einer ersten Rille (15) in dieser n-Schicht, die sich von einer oberen Oberfläche von dieser n-Schicht zu dieser p-Schicht erstreckt, in der eine erste Elektrode (7) für diese p-Schicht gebildet wird und es wird auch in dieser n-Schicht eine zweite Rille (9) zur Trennung von dieser ersten Elektrode gebildet, die die Rille (15) bildet, von einer zweiten Elektrode (8), die auf dieser n-Schicht in einem Bereich gebildet wird, der gegenüber von dieser ersten Elektrode (7) liegt;
   Bildung von dieser ersten Elektrode (7) auf dieser n-Schicht, die diese erste Rille (15) umgibt, für diese p-Schicht (5), die durch die erste Rille durchführt, um zu dieser p-Schicht in Verbindung zu kommen; und
   Bildung der zweite Elektrode (8) für die n-Schicht auf der oberen Oberfläche auf dieser n-Schicht, die mittels dieser zweiten Rille (9) getrennt wird.

10. Verfahren nach den Ansprüchen 8 oder 9, worin eine Bestrahlung mit Elektronenstrahlen bei einer Beschleunigungsspannung von 1 kV bis 50 kV und einem Abtaststrom von 0,1 µA bis 1 mA durchgeführt wird.

11. Verfahren zur Herstellung einer lichtemittierenden Halbleiter-Vorrichtung, die eine Verbindung einer Galliumnitridgruppe verwendet, umfassend:

   Bildung einer n-Schicht eines n-leitenden Halbleiters einer Verbindung einer Galliumnitridgruppe ($Al_xGa_{1-x}N$, worin $0 \leq x < 1$), mit einer Doppelschicht-Struktur, indem zuerst eine n^+-Schicht (3) von hoher Ladungskonzentration gebildet wird, in der die Elektronendichte hoch ist und dann eine n-Schicht (4) von niedriger Ladungskonzentration gebildet wird, in der die Elektronendichte niedrig ist;
   Bildung einer i-Schicht (50) eines Semi-Isolators eines Halbleiters einer Verbindung einer Galliumnitridgruppe ($Al_xGa_{1-x}N$, worin $0 \leq x < 1$), die mit p-leitenden Verunreinigungen dotiert wird, auf dieser n-Schicht (4);
   Bildung einer Rille (15) in dieser i-Schicht, die sich von einer oberen Oberfläche von dieser i-Schicht zu dieser n^+-Schicht (3) erstreckt, in der eine erste Elektrode (52) für diese n-Schicht gebildet wird;
   Bildung eines p-leitenden Bereichs (5) in einem speziellen Bereich in dieser i-Schicht (50), die in eine p-Leitung, mittels Bestrahlung mit Elektronenstrahlen, umgewandelt wird, wobei die-

ser p-leitenden Bereich so gebildet wird, daß diese erste Rille (15) von diesem p-leitenden Bereich (5) mittels dieser i-Schicht (50) getrennt wird;
Bildung einer ersten Elektrode (52) auf dieser i-Schicht (50), die diese erste Rille (15) umgibt, für diese n-Schicht, die durch die erste Rille (15) durchführt, um zu dieser n^+-Schicht (3) in Verbindung zu kommen; und
Bildung einer zweite Elektrode (51) für diesen p-leitenden Bereich auf einer oberen Oberfläche von diesem p-leitenden Bereich (5).

Revendications

1. Dispositif semi-conducteur émetteur de lumière (10) utilisant des composés du groupe de nitrure de gallium comprenant :

   une couche-n d'un semi-conducteur de composés du groupe de nitrure de gallium de type-n ($Al_xGa_{1-x}N$, où $0 \leq x < 1$)
   une couche-p (5) d'un semi-conducteur de composés du groupe de nitrure de gallium ($Al_xGa_{1-x}N$, où $0 \leq x < 1$) qui montre la conduction de type-p lors du dopage avec des impuretés de type-p et une irradiation avec des faisceaux d'électrons, ladite couche-p (5) joignant ladite couche-n ;
   une première électrode (8) pour ladite couche-n qui est formée sur une surface supérieure de ladite couche-p (5) afin de joindre ladite couche-n, traversant une première gorge (15) formée dans ladite couche-p (5) qui s'étend à partir de ladite surface supérieure de ladite couche-p jusqu'à ladite couche-n ; et
   une seconde électrode (7) pour ladite couche-p qui est formée dans une zone opposée à ladite première électrode (8), ladite zone étant sur ladite surface supérieure de ladite couche-p (5) et étant séparée de ladite première électrode (8) par une seconde gorge (9) formée dans ladite couche-p (5) afin de s'étendre à partir de ladite surface supérieure de ladite couche-p jusqu'à ladite couche-n.

2. Dispositif émetteur de lumière selon la revendication 1, dans lequel ladite couche-n est d'une structure à double couche composée d'une couche-n (4) de faible concentration de porteurs dans laquelle la densité d'électrons est faible et une couche-n^+ (3) de concentration de porteurs élevée dans laquelle l'intensité d'électrons est élevée, avec la première couche joignant ladite couche-p (5) et ladite première électrode (8) joint ladite couche-n^+ (3) de concentration de porteurs élevée.

3. Dispositif émetteur de lumière selon la revendication 2, qui comprend en outre un substrat de saphir (1) et une couche tampon (2) de nitrure d'aluminium (AlN) formés sur celui-ci, ladite couche-n^+ (3) de concentration de porteurs élevée étant formée sur ladite couche tampon (2).

4. Dispositif semi-conducteur émetteur de lumière utilisant des composés du groupe de nitrure de gallium comprenant :

   une couche-p (5) d'un semi-conducteur de composés de groupe de nitrure de gallium ($Al_xGa_{1-x}N$, où $0 \leq x < 1$) qui montre la conduction de type-p lors du dopage avec des impuretés de type-p et l'irradiation avec des faisceaux d'électrons ;
   une couche-n d'un semi-conducteur de composés du groupe de nitrure de gallium de type-n ($Al_xGa_{1-x}N$, où $0 \leq x < 1$), ladite couche-n joignant ladite couche-p (5) ;
   une première électrode (7) pour ladite couche-p (5) qui est formée sur une surface supérieure de ladite couche-n afin de joindre ladite couche-p (5), traversant une première gorge formée dans ladite couche-n qui s'étend à partir de ladite surface supérieure de ladite couche-n jusqu'à ladite couche-p (5) ; et
   une seconde électrode (8) pour ladite couche-n qui est formée dans une zone opposée à ladite première électrode, ladite zone étant sur ladite surface supérieure de ladite couche-n et étant séparée de ladite première électrode (7) par une seconde gorge (9) formée dans ladite couche-n afin de s'étendre de ladite surface supérieure de ladite couche-n jusqu'à ladite couche-p (5).

5. Dispositif émetteur de lumière selon la revendication 4, dans lequel ladite couche-n est d'une structure à double couche composée d'une couche-n (4) de faible concentration de porteurs dans laquelle la densité d'électrons est faible et une couche-n^+ (3) de concentration de porteurs élevée dans laquelle la densité d'électrons est élevée, avec la première couche joignant ladite couche-p (5), et ladite seconde électrode (8) est formée sur ladite couche-n^+ (3) de concentration de porteurs élevée.

6. Dispositif semi-conducteur émetteur de lumière utilisant des composés du groupe de nitrure de gallium comprenant :

   une couche-n d'un semi-conducteur de composés du groupe de nitrure de gallium de type-n ($Al_xGa_{1-x}N$, où $0 \leq x < 1$) ;
   une couche-i (50) semi-isolante d'un semi-conducteur de composés du groupe de nitrure de

gallium ($Al_xGa_{1-x}N$, où $0 \leq x < 1$) dopée avec des impuretés de type-p, ladite couche-i (50) joignant ladite couche-n ;

une première électrode (52) pour ladite couche-n qui est formée sur une surface supérieure de ladite couche-i (50) afin de joindre ladite couche-n, traversant une première gorge (15) formée dans ladite couche-i (50) qui s'étend à partir de ladite surface supérieure de ladite couche-i jusqu'à ladite couche-n ;

dans lequel ladite couche-n est de structure à double couche composée d'une couche-n (4) d'une faible concentration de porteurs dans laquelle la densité d'électrons est basse et une couche-n^+ (3) d'une concentration de porteurs élevée dans laquelle la densité d'électrons est élevée, avec la première couche joignant ladite couche-i (50), et ladite première électrode (52) joint ladite couche-n^+ (3) de concentration de porteurs élevée ;

une partie de type-p (5) dans une zone spécifique de ladite couche-i (50) qui est convertie en une conduction de type-p par irradiation avec des faisceaux d'électrons, ladite partie de type-p étant formée pour que ladite première électrode (52) soit isolée et séparée de ladite partie de type-p (5) par ladite couche-i (50) ; et une seconde électrode (51) pour ladite partie de type-p (5) qui est formée sur une surface supérieure de ladite partie de type-p (5).

7. Dispositif émetteur de lumière selon la revendication 6, qui comprend en outre un substrat de saphir (1) et une couche tampon (2) de nitrure d'aluminium (AlN) formés sur celui-ci, avec ladite couche-n^+ (3) de concentration de porteurs élevée étant formée sur ladite couche tampon (2).

8. Procédé de fabrication d'un dispositif semi-conducteur émetteur de lumière (10) utilisant des composés du groupe de nitrure de gallium comprenant les étapes de :

formation d'une couche-i (50) semi-isolante de semi-conducteur de composés du groupe de nitrure de gallium ($Al_xGa_{1-x}N$, où $0 \leq x < 1$) dopée avec des impuretés de type-p sur une couche-n du semi-conducteur de composés du groupe de nitrure de gallium de type-n ($Al_xGa_{1-x}N$, où $0 \leq x < 1$) ;

conversion de ladite couche-i (50) en une couche-p (5) qui montre une conduction de type-p en irradiant ladite couche-i avec des faisceaux d'électrons ;

formation dans ladite couche-p (5) d'une première gorge (15) s'étendant à partir d'une surface supérieure de ladite couche-p jusqu'à ladite couche-n dans laquelle une première électrode (8) pour ladite couche-n est à former et aussi formation dans ladite couche-p d'une seconde gorge (9) pour séparer ladite première gorge de formation d'électrode (15) à partir d'une seconde électrode (7) à former sur ladite couche-p (5) dans une zone de celle-ci opposée à ladite première électrode (8) ;

formation sur ladite couche-p (5) entourant ladite première gorge (15) de ladite première électrode (8) pour ladite couche-n qui traverse ladite première gorge pour joindre ladite couche-n ; et

formation sur ladite surface supérieure de ladite couche-p (5) séparée par ladite seconde gorge (9) de ladite seconde électrode (7) pour ladite couche-p (5).

9. Procédé pour fabriquer un dispositif semi-conducteur émetteur de lumière (10) utilisant des composés du groupe de nitrure de gallium comprenant les étapes de :

formation d'une couche-i (5) d'un semi-isolant de semi-conducteur de composé de nitrure de gallium ($Al_xGa_{1-x}N$, où $0 \leq x < 1$) dopée avec des impuretés de type-p ;

conversion de ladite couche-i (5) en une couche-p (5) qui montre une conduction de type-p en irradiant ladite couche-i avec des faisceaux d'électrons ;

formation sur ladite couche-p (5) d'une couche-n d'un semi-conducteur de composés du groupe de nitrure de gallium ($Al_xGa_{1-x}N$, où $0 \leq x < 1$) ;

formation dans ladite couche-n d'une première gorge (15) s'étendant à partir d'une surface supérieure de ladite couche-n jusqu'à ladite couche-p dans laquelle une première électrode (7) pour ladite couche-p est à former et aussi formation dans ladite couche-n d'une seconde gorge (9) pour séparer ladite première gorge de formation d'électrode (15) d'une seconde électrode (8) à former sur ladite couche-n dans une zone de celle-ci opposée à ladite première électrode (7) ;

formation sur ladite couche-n entourant ladite première gorge (15) de ladite première électrode (7) pour ladite couche-p (5) qui traverse ladite première gorge pour joindre ladite couche-p ; et

formation sur ladite surface supérieure de ladite couche-n séparée par ladite seconde gorge (9) de ladite seconde électrode (8) pour ladite couche-n.

10. Procédé selon la revendication 8 ou 9, dans lequel une irradiation avec des faisceaux d'électrons est réalisée à une tension d'accélération de 1 kV à 50 kV et un courant d'échantillonnage de 0,1 μA à 1

mA.

11. Procédé pour produire un dispositif semi-conducteur émetteur de lumière utilisant des composés du groupe de nitrure de gallium comprenant les étapes de :

formation d'une couche-n d'un semi-conducteur de composés du groupe de nitrure de gallium de type-n ($Al_xGa_{1-x}N$, où $0 \leq x < 1$) avec une structure à double couche en formant d'abord une couche-n^+ (3) d'une concentration de porteurs élevée dans laquelle la densité d'électrons est élevée et ensuite, la formation d'une couche-n (4) de faible concentration de porteurs dans laquelle la densité d'électrons est faible ;
formation d'une couche-i (50) d'un semi-isolant de semi-conducteur de composés du groupe de nitrure de gallium ($Al_xGa_{1-x}N$, où $0 \leq x < 1$) dopée avec des impuretés de type-p sur ladite couche-n (4) ;
formation dans ladite couche-i (50) d'une gorge (15) s'étendant à partir de la surface supérieure de ladite couche-i jusqu'à ladite couche-n^+ (3) dans laquelle une première électrode (52) pour ladite couche-n est à former ;
formation d'une partie de type-p (5) dans une zone spécifique dans ladite couche-i (50) qui est convertie en une conduction de type-p par irradiation de faisceaux d'électrons, ladite partie de type-p (5) étant formée de telle sorte que ladite gorge (15) est séparée de ladite partie de type-p (5) par ladite couche-i (50) ;
formation sur ladite couche-i (50) entourant ladite gorge (15) d'une première électrode (52) pour ladite couche-n qui traverse ladite gorge (15) pour joindre ladite couche-n^+ (3) ; et
formation sur une surface supérieure de ladite partie de type-p (5) d'une seconde électrode (51) pour ladite partie de type-p.

FIG. 1

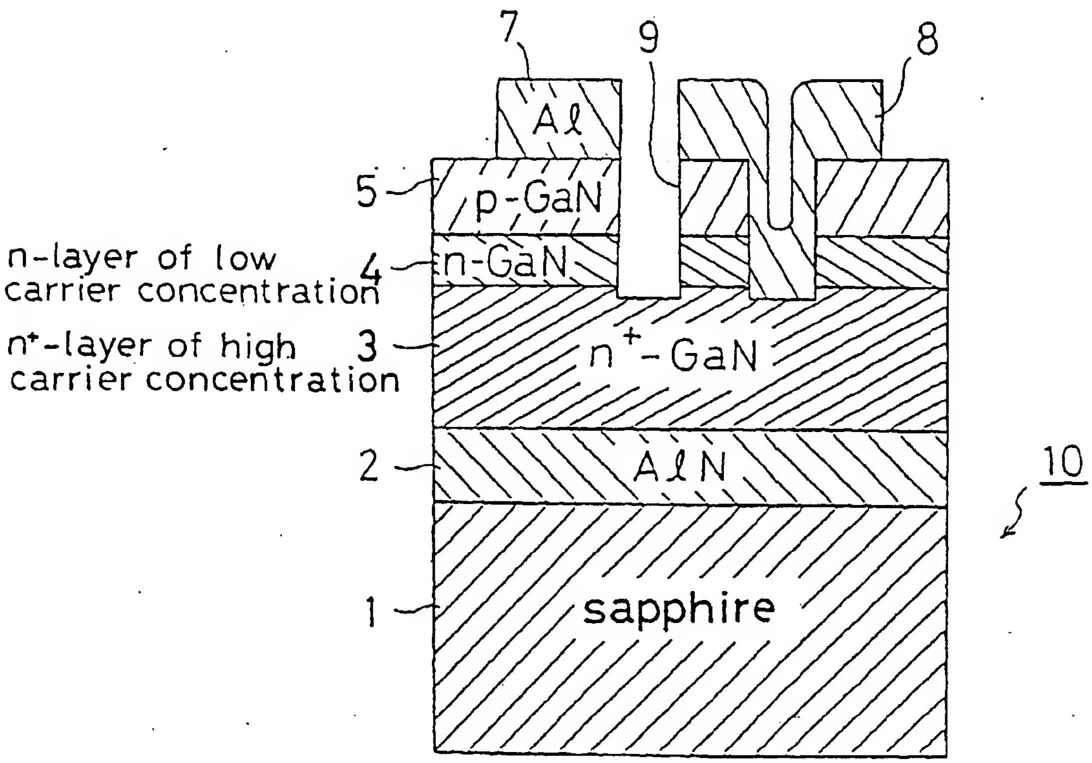

7
9
8
Aℓ
5
p-GaN
n-layer of low carrier concentration
4
n-GaN
n⁺-layer of high carrier concentration
3
n⁺-GaN
2
AℓN
10
1
sapphire

FIG. 2

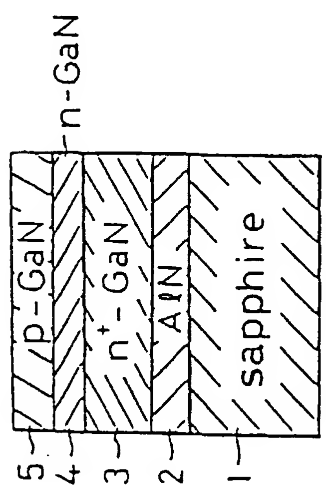


FIG. 3

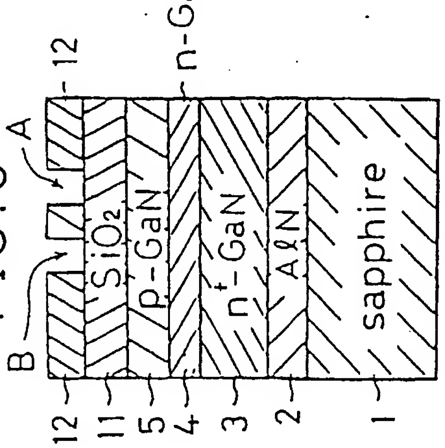


FIG. 4

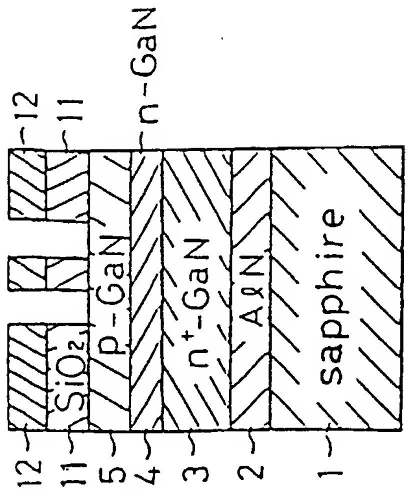


FIG. 5

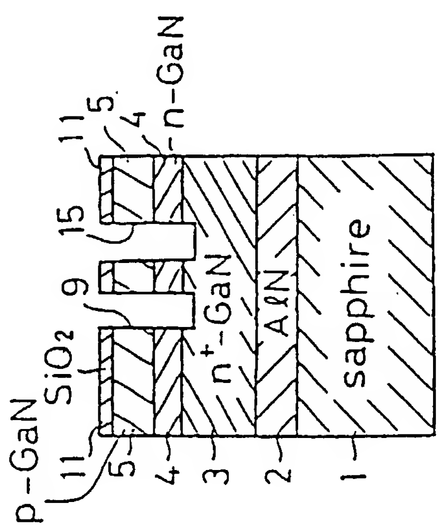


FIG. 6

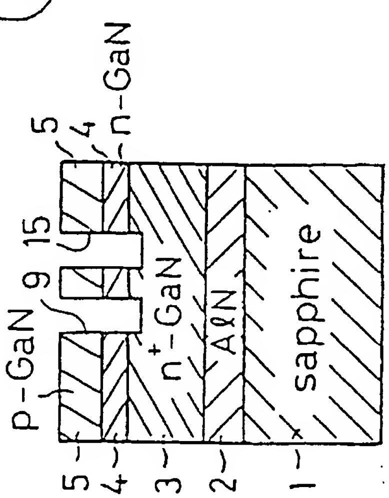


FIG. 7

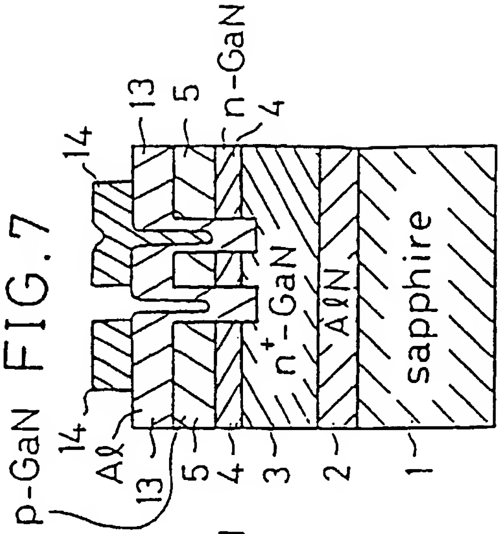


FIG.8B

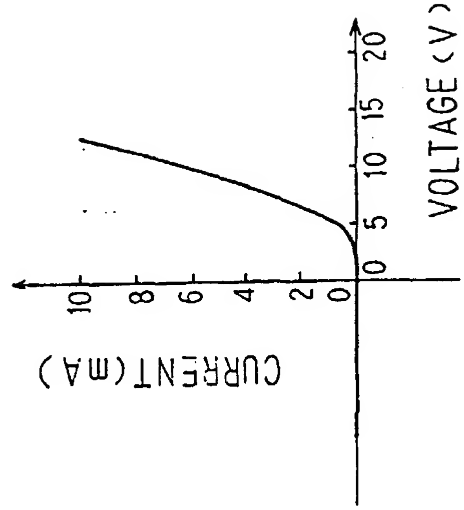

CURRENT(mA)
10
8
6
4
2
0
0
5
10
15
20
VOLTAGE(V)

FIG. 8A

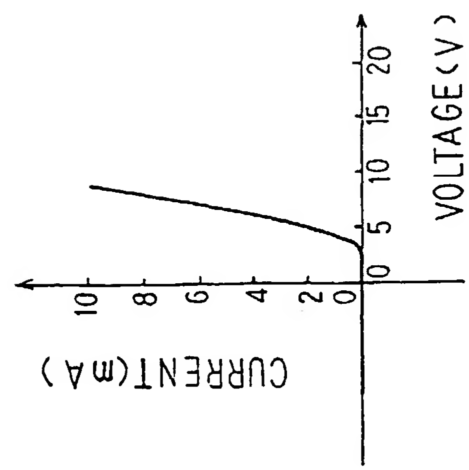

CURRENT(mA)
10
8
6
4
2
0
0
5
10
15
20
VOLTAGE(V)

FIG. 9

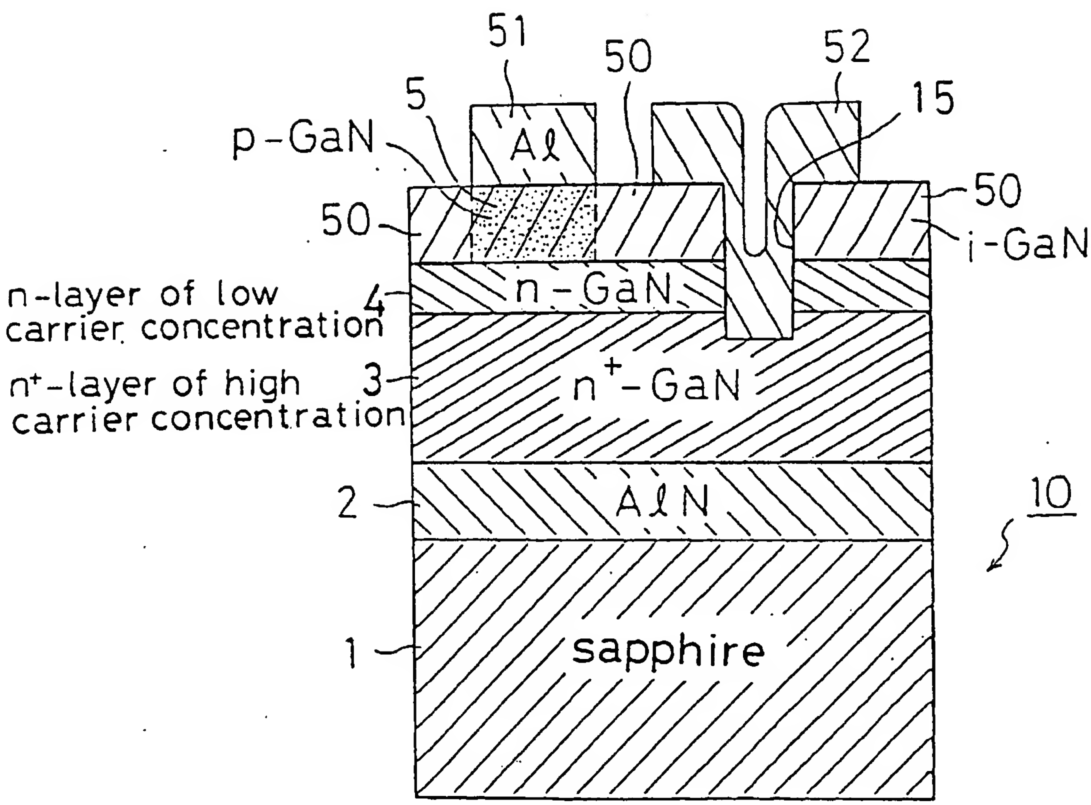

51
50
52
5
15
p-GaN
Aℓ
50
50
i-GaN
n-layer of low carrier concentration
4
n-GaN
n⁺-layer of high carrier concentration
3
n⁺-GaN
2
AℓN
10
1
sapphire

FIG.10

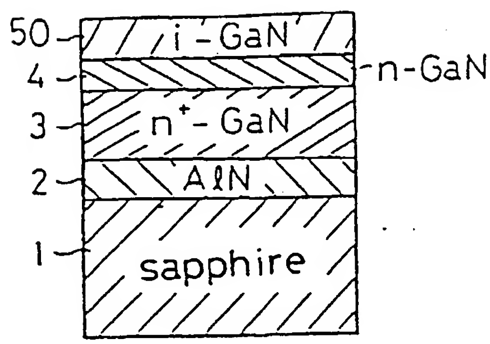


FIG.11

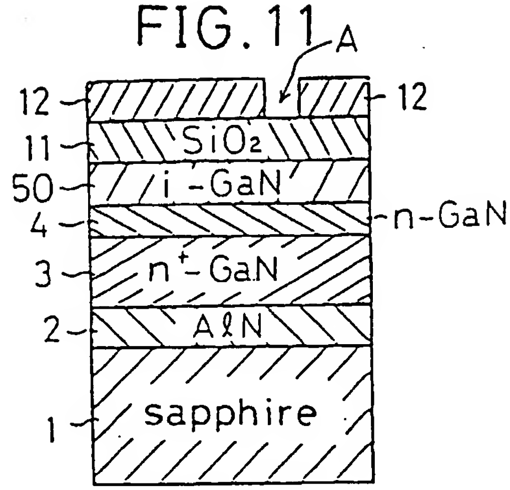


FIG.12

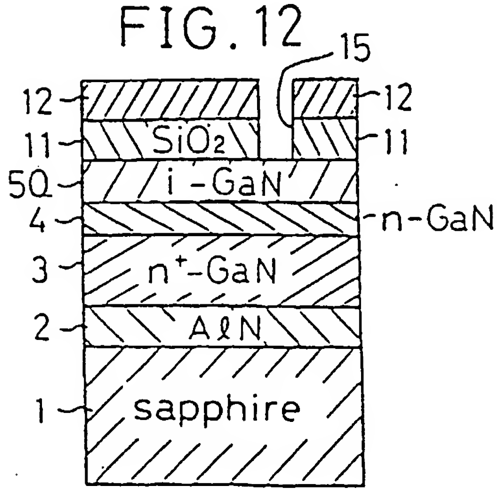
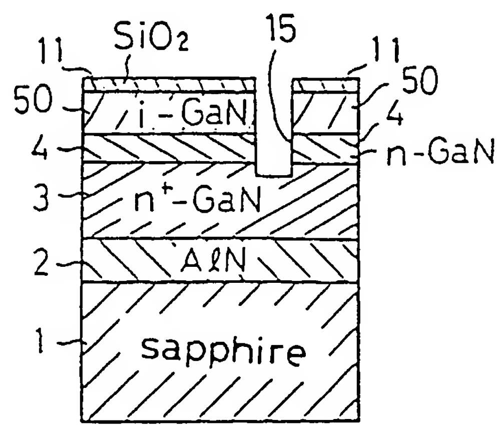


FIG.13



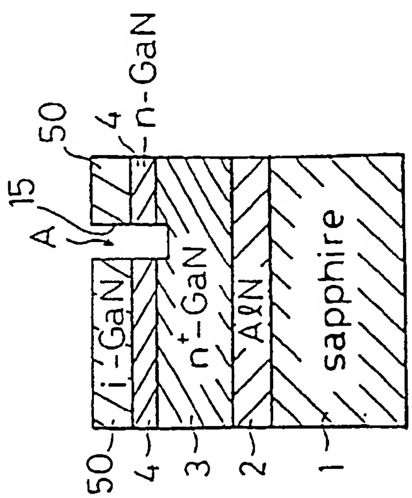


FIG.14

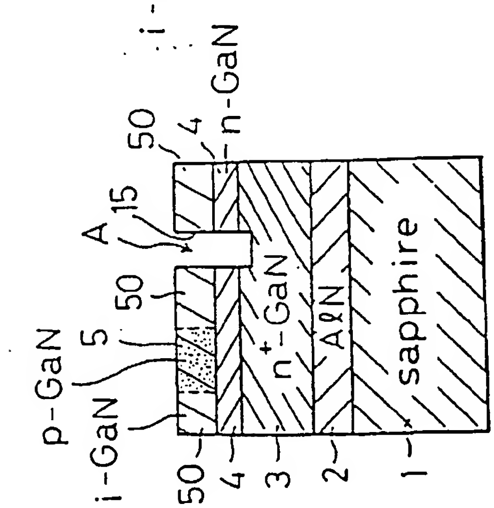


FIG.15

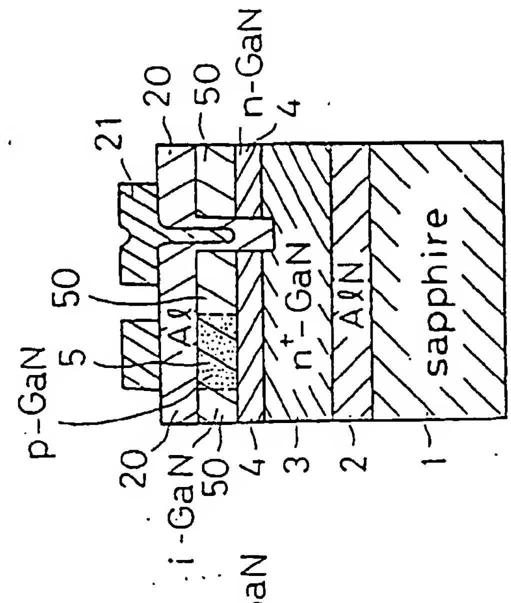


FIG. 16

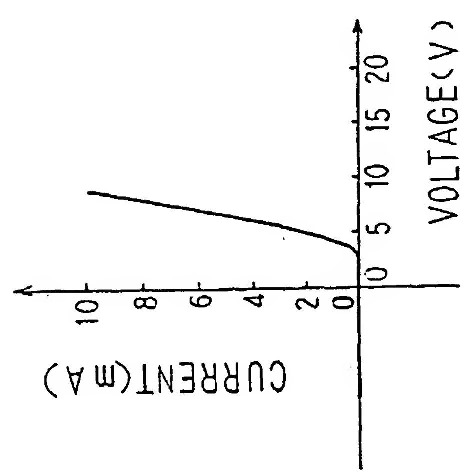


FIG. 17 A

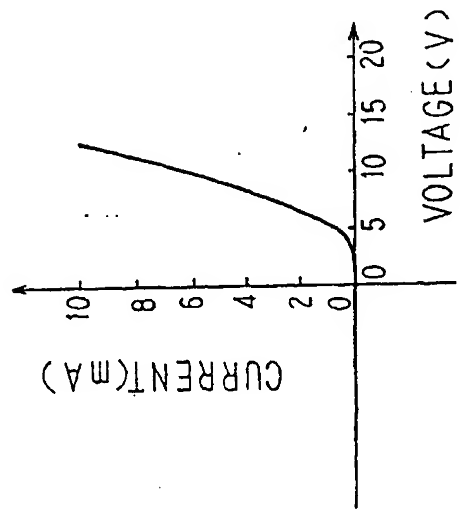


FIG. 17 B

FIG. 18